TECHNICAL ASPECTS OF DIVING IN ANTARCTICA

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Abstract

Diving in Antarctica presents the diver with problems related to the extreme environment, logistical and medical support, physiological stress, physical discomfort and danger. This paper describes the peculiar technical difficulties encountered by diving in such an environment and the ways in which equipment and diving procedures need to be modified in order to ensure the success of the program and minimise risk.

Key Words

Environment, equipment, marine animals, thermal problems.

Introduction

Australian National Antarctic Research Expeditions (ANARE) have undertaken diving programs in Antarctica over a period of many years. The programs have collected scientific data on human physiology, marine biology and ecology. Antarctica is one of the coldest continents on earth and requires divers to undertake special training and modify their usual equipment and diving protocols. The logistical problems of an Antarctic diving program are extensive and as much a challenge to the diver as the environment itself.

The environment

Most ANARE diving programs have been undertaken at Davis Station, Antarctica. Davis (68°35'S, 77°58'E) is a permanently occupied Australian research station and is situated on the edge of the Vestfold Hills, Princess Elizabeth Land, 4,700 km across the Southern Ocean from Perth. The hills are of moderate relief and are penetrated by many deep fjords which extend inland to the ice plateau.

The weather at Davis is relatively mild. The Vestfold Hills are interposed between the station and the ice plateau and this land mass breaks up the catabatic winds and modifies the local climate. Consequently, Davis enjoys a low average wind speed of 20 km/hr and clear, still days. The mean temperature ranges from 0°C in summer to -18°C in winter. The continent is very dry with only 5-12 cm of precipitation per year and has a low level of humidity. Daylight hours vary from 0 hours per day in the winter to 24 hours per day during the summer.

The ambient temperature has the most influence on sea and ice conditions. The sea begins to freeze in March after the short summer season. Fast sea-ice is present from March/April until December/January and may extend several hundred kilometres off-shore and reach a thickness of 1.4 to 2.0 m in the late winter.[1-4] Increasing temperatures, winds and ocean swells cause this fast ice to "breakout" in the spring although it may remain in the fjords for much longer.

Salinity depresses the freezing point of sea water to approximately -1.8°C and after the fast ice has formed the sea is relatively insulated from the winter extremes above. Consequently, water temperature varies little, from 0°C to -2.0°C throughout the year.[1-6] Diving visibility is excellent and typically greater than 100 m.[3,5] It is at its maximum during winter and spring when the fast ice cover reduces turbulence and sediment suspension and low light intensities depress phytoplankton (algal) growth. Light under the ice may be limited at certain times of the year by short hours of daylight, the low angle of incident light and ice thickness. Algal bloom may first appear in September and may greatly decrease visibility from December onwards.[2,5]

The seas around Davis are prone to the usual ocean currents and tides. These are modified by fast ice cover which nullifies the effects of wind and minimises tidal fluctuations. However, the sea remains a dynamic force beneath the ice and dangerous currents may be present especially near the estuaries and narrow inlets of some fjords.

Dangers

Environmental hazards above the ice present major difficulties in Antarctic diving. Hypothermia may be seen among divers, attendants and support staff as a result of exposure to low temperatures, wind and wet clothing.[4] Frostbite is not uncommon and results from freezing of water within skin cells following intense, cold-induced vasoconstriction. It affects the exposed areas especially the cheeks, ears, nose and fingertips.

Hypothermia may also be a problem below the waterline.[1,4] Sullivan and Vrana[1] demonstrated a slowly progressive central hypothermia in Antarctic divers. This hypothermia is likely to be a major cause of physiological depletion in divers and motor and mental deterioration may affect their performance, comfort and safety.[2,4] Peripheral hypothermia results in digital discomfort, facial pain and the loss of peri-oral muscle control if the face is directly exposed to water. Continued underwater exposure results in localised cooling with the hands and feet exhibiting the most rapid rate of heat loss. These cool rapidly because they have the greatest skin surface area to mass ratio, little subcutaneous fat and relatively little insulation to allow dexterity.[2]

Ultraviolet (UV) radiation may be intense in Antarctica. The spatial and temporal variation of stratospheric ozone above Antarctica is of regional and global significance to the amount of UV radiation that reaches the ground.[7] Divers and their attendants are at particular risk from UV injury because of their exposure to direct radiation and that reflected from ice, snow and the water. Protection of the skin from sunburn and the eyes from snow-blindness is of great importance, particularly during the long hours of sunshine in the summer.

Marine animals are potentially dangerous to Antarctic divers.[2] The Leopard seal is a four metre, toothy, aggressive predator which feeds on krill, penguins and other seals. There have been no reported incidents of these animals injuring divers but harassment has occurred which necessitated the abandonment of the dive. ANARE diving regulations forbid diving activity within 400 m of a Leopard seal.[2] Non-breeding male Elephant seals "haul out" at Davis in summer. They are approximately 3.5 m in length, although may reach six metres and 3-4 tonnes in full fat when fully grown. There is a documented incident of an Elephant seal biting a diver on the shoulder and it is recommended that great care be taken if diving in the vicinity of breeding males in violent rut. An underwater encounter could be most embarrassing! Killer whales have a reputation as being ruthless and ferocious killers who feed on seals, walrus and penguins. Their exact threat to humans is uncertain and they should be considered as an unpredictable and potentially serious hazard.

Antarctic diving, especially under-ice, has its own peculiar dangers. Solo diving is often undertaken with a fully-suited "buddy" waiting at the surface. This arrangement ensures at least one diver free from hypothermia and exhaustion at any one time. As few divers are available it also avoids the need for multiple dives thus minimising the risk of decompression sickness (DCS). Tides and currents may cause difficulties as in any marine environment and may even cause diver entrapment by moving ice floes or closing up tide cracks in the ice through which the diver entered. Under-ice gloom may contribute to diver disorientation and claustrophobia but should be avoided with the use of adequate illumination.

Antarctic divers are at risk of dysbaric and non-dysbaric diving illnesses as well as illnesses unrelated to diving.[6] Divers are potentially more at risk from DCS in Antarctica. The water is very cold, and often dark, and the underwater work is made even heavier by the use of cumbersome suits.[8] Diver exhaustion is a potential problem and may result from hypothermia, heavy underwater work, cumbersome suits, the demands of the diving program and insomnia during the long hours of summer daylight.

Communications are particularly important in Antarctic diving programs. The interpersonal communications of those in the diving team must be good with an adequate designation of personal responsibilities and responsible leadership. Communication between the dive team in the "field" and Davis Station needs to be fail safe in the case of emergency. Radio schedules, spare radios and batteries are prerequisites.

Equipment

The recreational scuba regulator is prone to malfunction in Antarctic diving conditions.[2,5] The usual cause is ice crystal formation within the regulator mechanism which results in jamming or "freeze up". There are several factors which may precipitate first stage freeze-up. Firstly, adiabatic (without loss or gain of heat) expansion of air from the scuba cylinder results in cooling of the air as it expands from high to low pressure. This causes moisture in the air or water in the regulator mechanism to freeze. Secondly, the delivery of wet air to the regulator from the cylinder makes freeze up more likely. This is not usually a problem in Antarctica as the air delivered into the compressor is usually very dry. Thirdly, as modern first stages are metallic and very compact, they may become supercooled in the very cold atmosphere even before the first breath is drawn. This problem may be overcome by keeping the regulator in the relatively warm diving shelter until immediately before the dive. Ice crystals once generated may plug orifices or interfere with the movement of first stage components. Fortunately, first stage freeze up nearly always causes malfunction in an open or free-flow position.[2,5]

Second stage freeze-up is caused by moisture in the exhaled breath or water in the chamber forming ice around the demand lever. It is more likely to occur if the second stage is purged or allowed to free flow, conditions which rapidly decrease the regulator temperature. Unlike the first stage, second stage freeze up may result in no air getting to the diver. It is recommended that regulators be dried completely after the post-dive rinse and that no water be allowed to enter the second stage before immersion.

Ice formation on the external surfaces of the first and second stage assemblies is also possible. Usually ice forms around the large first stage spring which is surrounded by water in most regulators. This results in jamming of the spring with loss of depth compensation, restricted breathing or free-flow. Free-flow produces an increase in intermediate air pressure which in turn may cause free-flow of the down-stream second stage demand valve and second stage freeze up. ANARE uses the Sherwood Magnum Blizzard regulator which has been specifically designed for under-ice diving. This regulator has compressed air surrounding the first stage main spring which provides a form of insulation and reduces the incidence of freeze up in this assembly.[2] Other cold water regulators are insulated by 50% glycerol surrounding the first stage.[3]

The likelihood of regulator freeze up may be minimised by avoiding rapid flows of air from the scuba cylinder. Lengthy purging or inflation of the buoyancy compensator (BC) or dry suit, free-flow and the use of the octopus assembly is avoided where possible. Water must not be allowed to enter the regulator between dives and its exposure to extreme cold prior to use is discouraged. Inhalation from the regulator should be avoided until it is well below the water surface and gentle exhalation whilst descending through the surface layer of ice slush is recommended.[3] This avoids the use of the supercooled stages in the very cold atmosphere. The attachment of a small "pony" cylinder to the main scuba cylinder is highly recommended. This small unit has its own regulator and is a completely separate air supply which may be utilised in the event of main regulator freeze up.

A bank of large cylinders may be used to provide a surface air supply with air being delivered via an umbilical hose. This has the advantage of eliminating the scuba first stage, provides a very large reservoir of air and an effective safety line to the diver. These air banks have the disadvantage of being extremely heavy and require either helicopter or sled transport.

The Kirby-Morgan helmet, or "band mask", is a device which encloses the diver's entire face and has been used extensively on ANARE expeditions. It has the advantage of incorporating the second stage into the relatively warm air within the mask, prevents very cold water from contacting the face and allows the diver to communicate with the surface by an intercom system. However, the helmet is cumbersome and time-consuming to don, provides substantial water drag, restricts head movements and requires a considerable amount of familiarisation training.

Communication with surface attendants is essential in under-ice diving especially if the diver is diving alone. In this situation there can be no immediate reliance upon a buddy diver in the event of emergency. All under-ice divers must be attached to a life-line. The diving attendant should hold the life-line reasonably taut at all times and should be able to communicate with the diver through a predetermined sequence of tugs.[2] The life-line also allows the diver to find the entrance hole and the rescue diver to find the diver, if necessary. The wires of the Kirby-Morgan helmet intercom system run with the life-line. This intercom is an ideal system but, like many things in Antarctica, is prone to malfunction.

Ten mm wet suits are sufficient but cumbersome in Antarctic conditions. The dry suit has become popular as, when worn with the appropriate underwear, it provides excellent insulation from cold and wind and avoids the cold discomfort of changing out of a wet suit. The Poseidon Unisuit, used on ANARE expeditions, is built from closed cell foam neoprene with nylon lining both sides and is donned through an access sealed by a waterproof zipper. The suit is inflated by an inlet valve connected to the diver's air supply and exhausted by a second valve adjacent to the diver's shoulder. Thus, two valve manipulation allows for complete buoyancy control.

Drysuits, because they use air as insulation, require more weight to get the wearer below the surface and have more buoyancy problems than wet suits. It is essential to have training in how to dive wearing a dry suit in order to learn how to control the problems of shifting air inside the suit. One technique is to use a buoyancy compensator (BC) for buoyancy control and only add sufficient air to the dry suit to fill the underwear at the surface.

If a dry suit is worn an additional BC is theoretically unnecessary. However, some divers elect to wear a BC and dry suit. The BC may then be used for all buoyancy control or as a back up in the event of dry suit failure.

In the last seven years dry suits have gone from being rarities in Australia to being almost the standard suit in southern waters. The situation in April 1996 is that the majority of divers undertaking dives over 30 m are wearing drysuits. In the Scottish Sub-Aqua Club Survey in 1995 83% of the respondents dived in dry suits in conditions similar to those in Tasmania and Victoria.[9] The deciding factor is the vast improvement over the wet suit in keeping the diver warm. Without the misery of incipient hypothermia the diver can concentrate on enjoying the dive and is in a better state to cope with emergencies.

The dry suit has several disadvantages. Donning the suit can be time-consuming and hard work although this is minimised if detergent is used to lubricate the tight seals at the neck and wrists. The suits are bulky, cause considerable water drag and may exhaust the diver if considerable swimming is required. Dangerous over-inflation of the suit may be caused by inflation or exhaust valve freeze up or malfunction and may require the diver to vent excess air through a wrist seal. As with regulators, supercooling of suit valves prior to the dive and prolonged use of the inflation valve predisposes to valve freeze up. Thigh and ankle weights are often required to maintain the diver in the head-up position and to prevent air migration to the foot area if diver becomes head-down. If sufficient air does migrate to the foot area the diver may rapidly become inverted and his fins "pop" off. With or without fins, the diver may not be able to right himself and may lose buoyancy control as suit air migrates away from the exhaust valve. The dry suit must be sized correctly. This will limit the volume of air in the event of over inflation, avoid "suit squeeze" from folds of excess suit material and popping of the fins if the suit legs are too long. While air has been used traditionally for dry suit inflation, the use of argon gas to significantly reduce heat loss during a dive has been recommended.[3]

A major disadvantage is that if the suit is damaged and water gets in thermal protection is lost and, unless the diver is using a buoyancy compensator, the diver rapidly becomes negatively buoyant.

Hot water suits, which allow hot water from the surface to flow over the diver's bodies, are an efficient method of keeping divers warm. They are used in similar temperatures in deep water off shore in the oil industry, but have not been used in ANARE diving because of the logistic problems involved with transporting the heaters.

Pollock[5] has reported the use of dive computers in Antarctica. He examined the use of the Beauchat Aladin and Orca Edge models and found that primary computer functions operated normally despite marked shortening of battery life.

Diving gloves require modifications for cold water conditions. Ideally, a neoprene mitten glove is worn to allow the fingers to warm each other. However, this arrangement causes loss of dexterity and most gloves are a compromise with separate compartments for the thumb and index finger. The addition of hot water into the gloves immediately prior to the dive prolongs the time before digital discomfort ensues.[2]

Emergency equipment must be adequate and well maintained. First-aid equipment and oxygen must be available at the dive site and a recompression facility is advisable on station. ANARE transports a recompression chamber to Davis for each diving program although the logistics of transport and the time involved in training and commissioning of this chamber are considerable.

Logistics

Each member of the diving team must be psychologically and physically fit, and skilled and trained in special ice-diving techniques. The divers must have considerable experience in deep diving, penetration diving, diving in circumstances of poor visibility, night diving and must be skilled in first-aid and rescue techniques.[2] ANARE runs a diver training course in Australia and Antarctica which familiarises divers with the equipment and techniques which will be used.

Equipment assembly, maintenance and transport to Antarctica is a exhaustive process. Attention must be given to the adequacy of spare parts and contingency plans devised in the event of unforeseen circumstances. In Antarctica an equipment storage and maintenance facility needs to be established in a warm and convenient location with easy access to transport, washing and air compression facilities.

Dive site selection and camp movement may be undertaken by helicopter or over-ice vehicles. Helicopters are usually used during the summer when over-ice transport may be limited by melting and cracking of the sea-ice. Camp facilities include a fibreglass "apple" hut, tents, heating and cooking equipment, radio gear, rescue equipment, bedding, spare clothing as well as the diving equipment. Food and fuel for several days is carried in the event of a blizzard and isolation in the "field".

Conclusion

The dangers, difficulties and frustrations of diving in Antarctica are considerable. For every hour spent underwater there are hundreds of hours of planning, preparation and training. The technical aspects of this type of diving differ in many respects from diving in temperate or tropical waters and are directly related to the environmental temperatures. Most of the difficulties encountered usually involve maintenance or malfunction of the specialised equipment which needs to be used. Despite the cold and wet, the isolation and the sacrifices involved, Antarctic diving provides unparalleled experiences for those who make the effort.

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PAIN PERCEPTION DURING SCUBA DIVING

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Key Words

Equipment, investigations, pain.

Introduction

It is a common experience during scuba diving that small injuries like scrapes and cuts from sharp stones, shells or wrecks seem to be unnoticed until after the dive. It seems that the threshold for pain is higher during scuba diving than it is when on land. We have no explanation for this phenomenon, and to be absolutely honest, we do not even know if it is true. A study was therefore designed to find out if this experience is real and to explore different explanations for this phenomenon.

It is know that nitrogen is a narcotic gas, and as the content of nitrogen is increased in the tissues during diving, this could offer a possible explanation. Another fact is that nerve conduction from the nociceptors in peripheral tissues is lowered by cooling of the tissues.[1-3] Cooling of the skin might thus be an explanation of an increased pain threshold. Another explanation might be that during a dive one is concentrating and ignores pain.

Pain physiology

In 1979, the International Association for the Study of Pain defined pain as *an individual experience of a potential or an actual tissue damage, unpleasant sensory experience, or experienced as such.*

This is a very broad definition. In daily life we often use a very simple classification such as acute or chronic pain. This does not work very well in the orthopaedic clinic, so in our clinic and in research, we use another classification.

Nociceptive pain is an acute pain which is caused by damage to tissues, either actual or potential damage. This is a type of pain one experiences when one cuts or bruises oneself and when one breaks a leg.

Neurogenic pain is caused by a prior damage to one's neural tissues and gives rise to phantom limb pain, trigeminal neuralgias, reflex sympathetic dystrophies and so on.

Another group is the chronic pains. Chronic pain syndromes, such as chronic low back pain etc., are a very difficult group to treat.

Finally there is psychogenic pain, a group of pain syndromes associated with psychic disturbances.

When a painful stimulus is applied to peripheral tissues a number of nociceptors are engaged (mecano-receptors, thermo-receptors or chemo-receptors) and impulses are conducted along two types of nerves to the posterior horns of the medulla. First through thick myelinated fibres which give a very sharp and distinct pain and later by thin nerve fibres, without myelin, which give a duller and more lasting pain. This conduction can be modulated by other non-painful sensory input, the so-called gate control.

When one damages the nociceptors in the periphery there is also an inflammatory reaction with an outflow of vasoactive agents, such as histamine, prostaglandins etc.

The pain impulses are conducted through the posterior columns of the medulla to the brain where they enter different pain centres. Most importantly, one in the cortex which is responsible for the localisation of pain. But also in the cortex there is a descending pain inhibition centre from which signals are sent down to the spinal cord to further filter pain signals. Others centres are in the limbic system, responsible for the emotional reaction to pain, the basal ganglia which are responsible for the tremor or dizziness which are seen in pain and the hypothalamus, responsible for the discomfort and nausea which often occurs with pain.

Methods

In order to measure pain levels and thresholds we, at the Danish Pain Research Centre, normally use an electronic pressure algometer. This electronic device measures pain